High Energy Density Physics (HEDP) Capabilities at the Linac Coherent Light Source (LCLS)

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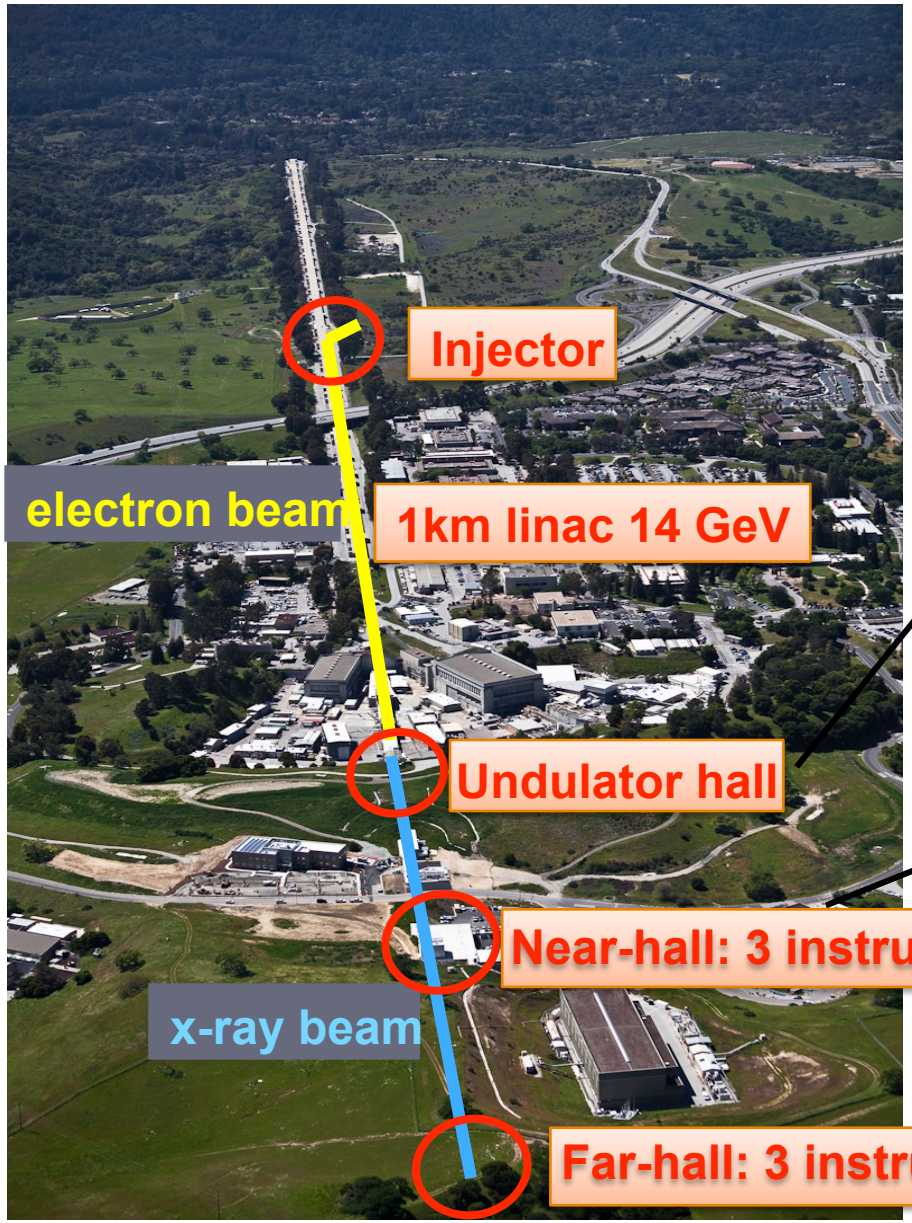
U.S. DEPARTMENT OF ENERGY
Office of Science

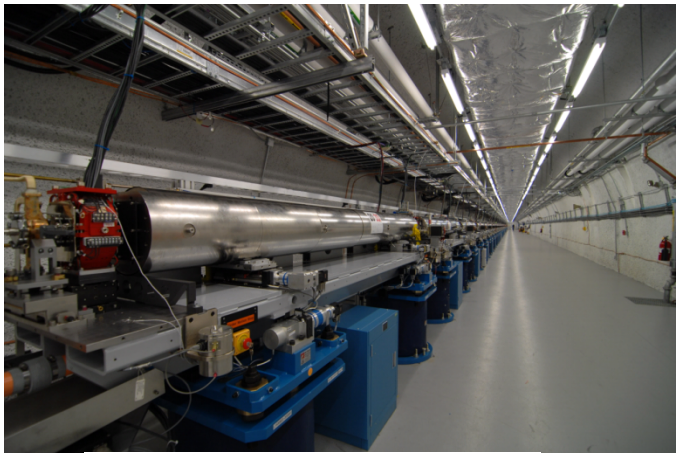
SLAC NATIONAL ACCELERATOR LABORATORY

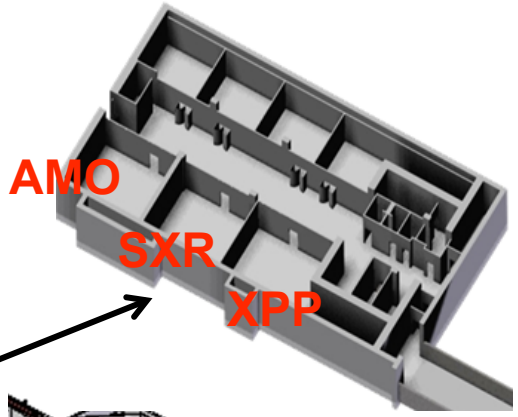
Outline

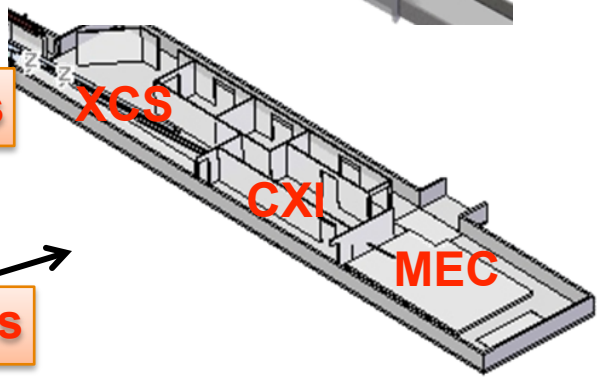
- An introduction to the LCLS Free Electron Laser facility.
- The capabilities of the LCLS MEC instrument.
- Summary

Linac Coherent Light Source (LCLS)









Experimental Halls and Operations Schedules

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Near Experimental Hall

AMO
SXR
XPP

X-ray Transport Tunnel
200 m

XCS
CXI
MEC

	Start of operation
AMO	Oct-09
SXR	May-10
XPP	October-10
CXI	February-11
XCS	November-11
MEC	April-12

Far Experimental Hall

AMO: Atomic, Molecular and Optical
SXR: Soft X-Ray materials sciences
XPP: X-ray Pump-Probe

XCS: X-ray Correlation Spectroscopy
CXI: Coherent X-ray Imaging
MEC: Materials under Extreme Conditions

LCLS Machine Performance

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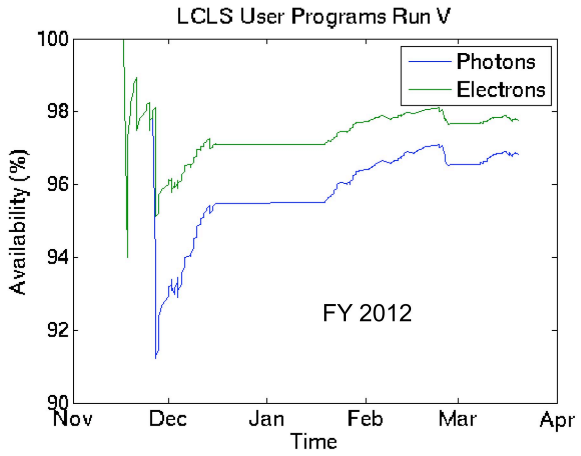
	Baseline performance	**Current performance**
Photon energy range	830 to 8300 eV	**480 to 10,000 eV**
FEL pulse length	230 fs	**5 - 500 fs**
FEL pulse energy	up to 2 mJ	**up to 4 mJ**



95% photon availability

LCLS produces x-rays with high peak intensity (photons/fs).

X-rays either (i) Make HED matter or (ii) Probe HED states prepared by optical lasers.

LCLS Proposal Process

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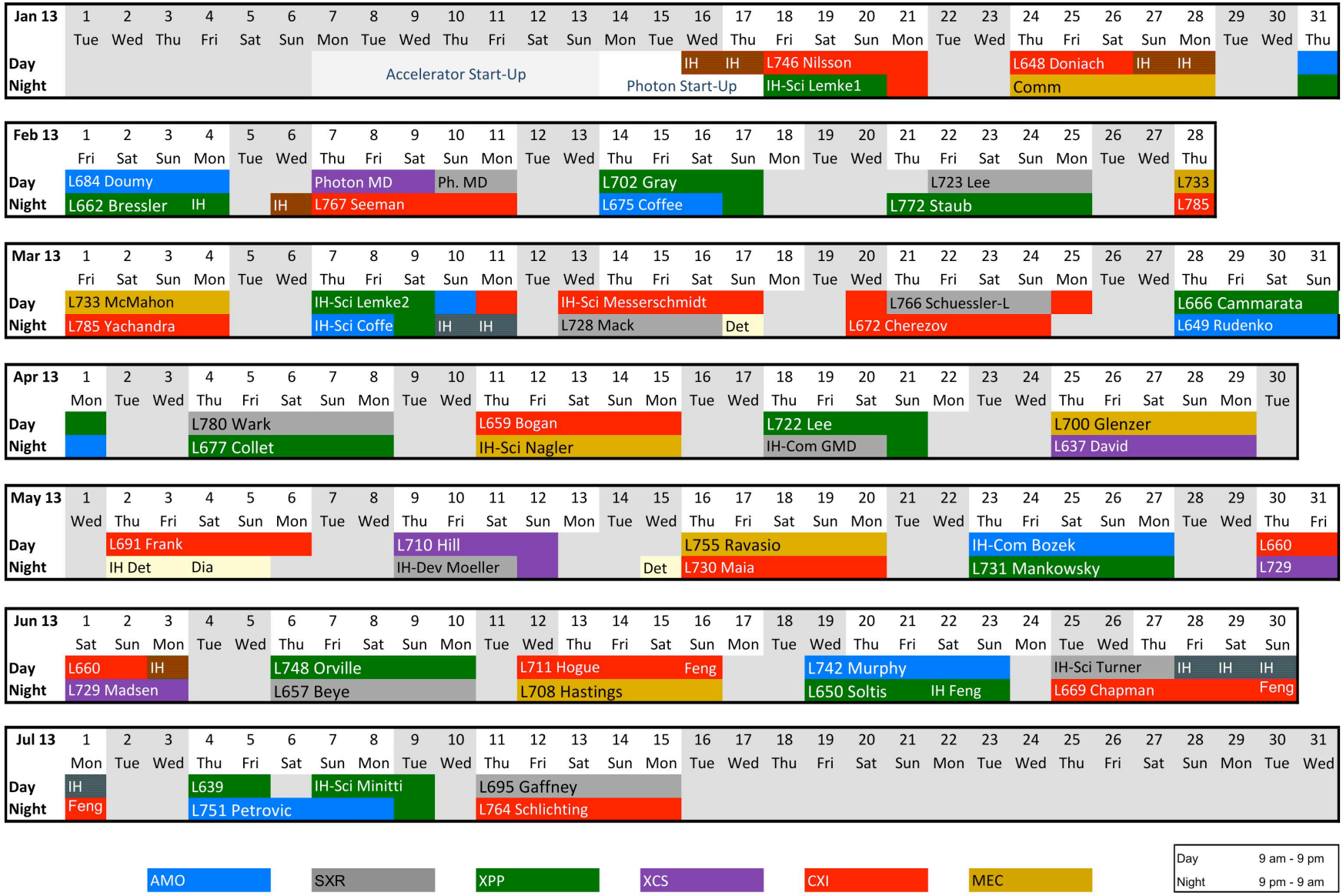
- Proposal deadlines ~ every 6 months, last January 15
- Format: experimental team, scientific case, experimental procedure.
- Proposal Review Panel: includes a High Energy Density Science subpanel.
- ~ 25 % of proposals receive beamtime.
- Independent process for LCLS instrument scientists to submit proposals for a fraction of the beamtime.

LCLS Run 7 Schedule



LCLS Materials under Extreme Conditions (MEC) Instrument

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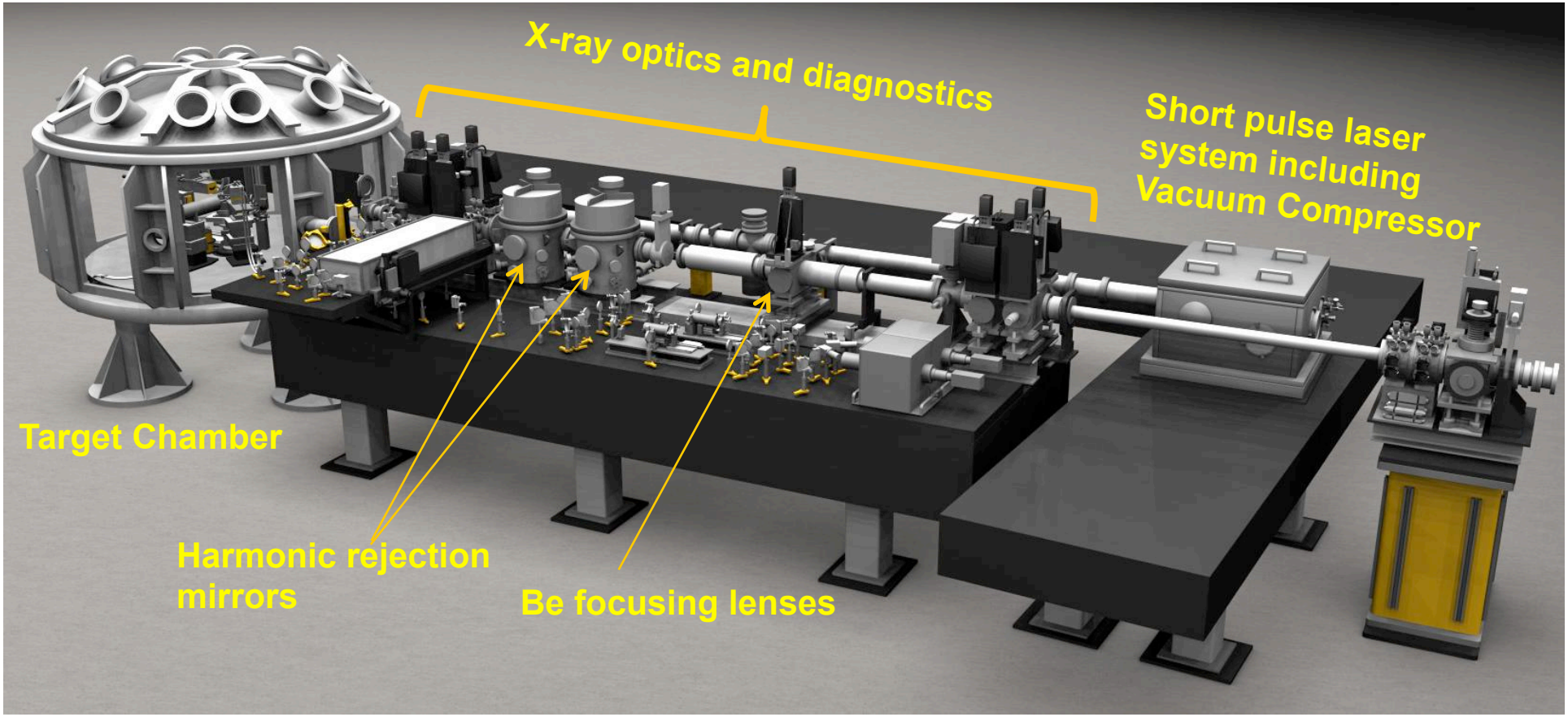


- MEC commissioning began at the end of January 2012.
- First user experiment at MEC April 2012 (very aggressive).

MEC Instrument Team

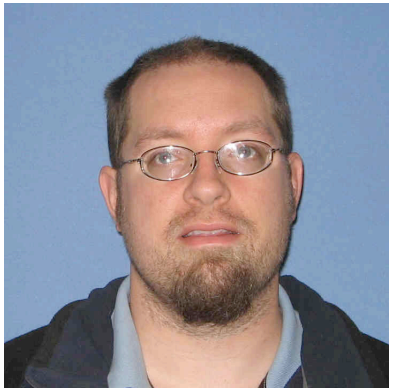
Phil Heimann
Department Lead

Hae Ja Lee
Instrument Scientist

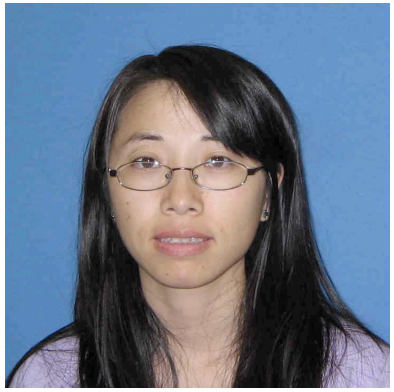
Bob Nagler
Instrument Scientist

Eric Galtier
Research Associate

Marc Welch
Laser Engineer



Brice Arnold
Instrument Engineer



Jing Yin
Controls,DAQ Engineer

Ruben Curiel
Area Manager

MEC Provides Strong User Support

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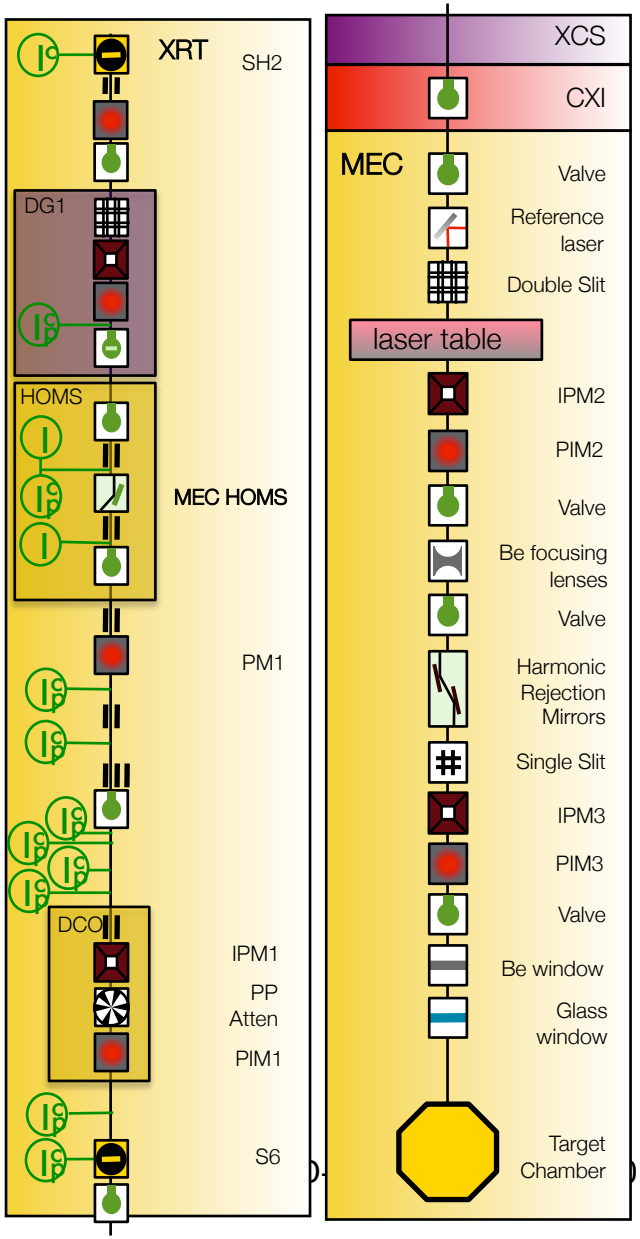
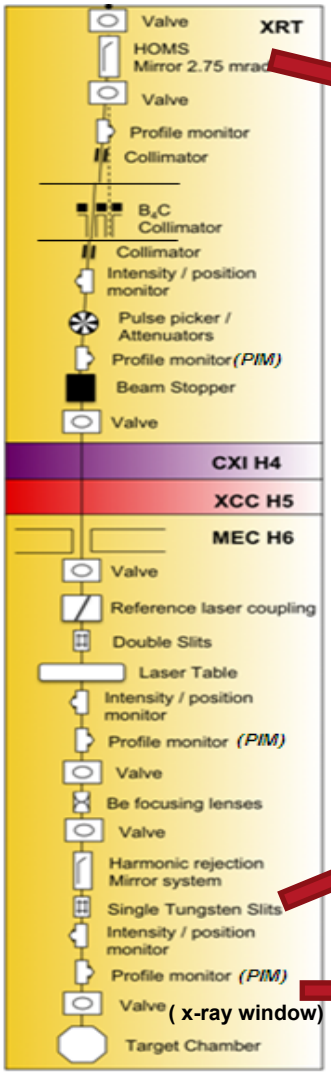
- Telephone meetings take place regularly before the beamtimes.
- MEC is responsible for a large fraction of the experimental setup, which changes significantly for each beamtime.
- There is a minimum of 1 week setup time before the beamtime.
- At least 1 instrument scientist or research associate is present throughout the beamtime.
  - Necessary because of the short beamtimes: 5 shifts of 12 hours.

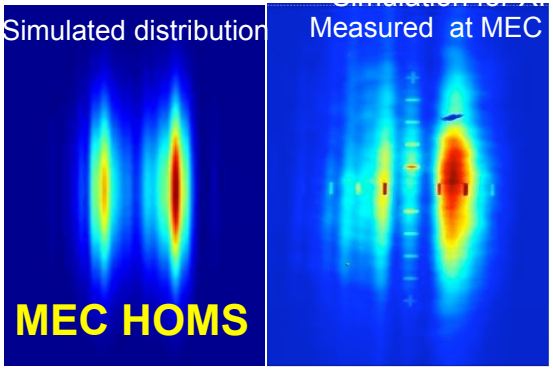
MEC X-ray Optics and Diagnostics

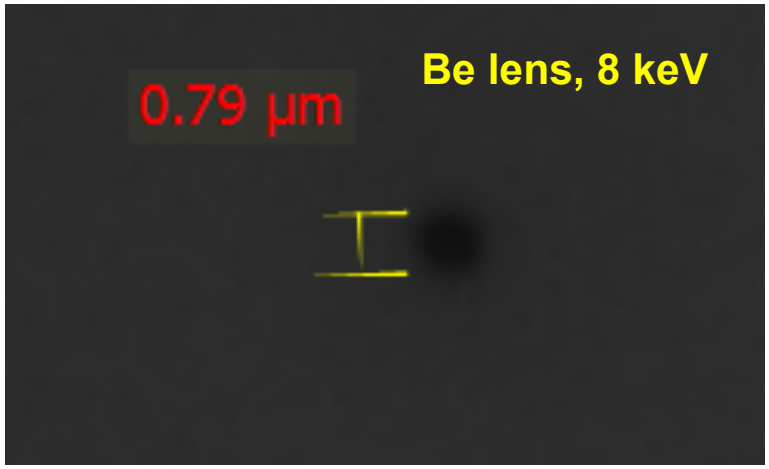


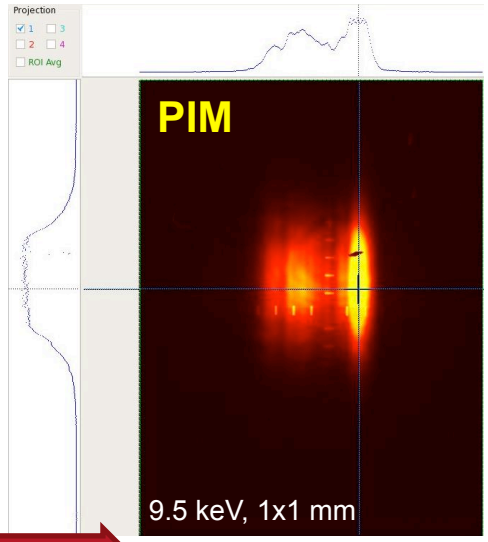
Requirement	Device
Steer the beam to MEC	MEC HOMS mirror
Monitor the beam steering to MEC	Profile Monitor (PM)
Characterize X-ray pulse intensity	Intensity Position Monitor (IPM)
Characterize X-ray spatial profile	Profile Intensity Monitor (PIM)
Tailor X-ray intensity and spectrum	Attenuators
Tailor X-ray repetition rate	Pulse Picker
Offline Alignment	Reference Laser
Tailor X-ray spatial profile (> 50 μm)	Slit system
Tailor X-ray spatial profile (1~ 50 μm)	Be Focusing Lenses
Tailor X-ray spectrum	Harmonic Rejection Mirrors
Allow X-ray beam into target chamber	Be window
Allow reference optical laser into target chamber	Glass window
Provide environment for experiment	Target chamber
Create high pressure or WDM status	MEC Laser Systems
Measure the spectrum and phase	Target Diagnostics

MEC X-ray Commissioning





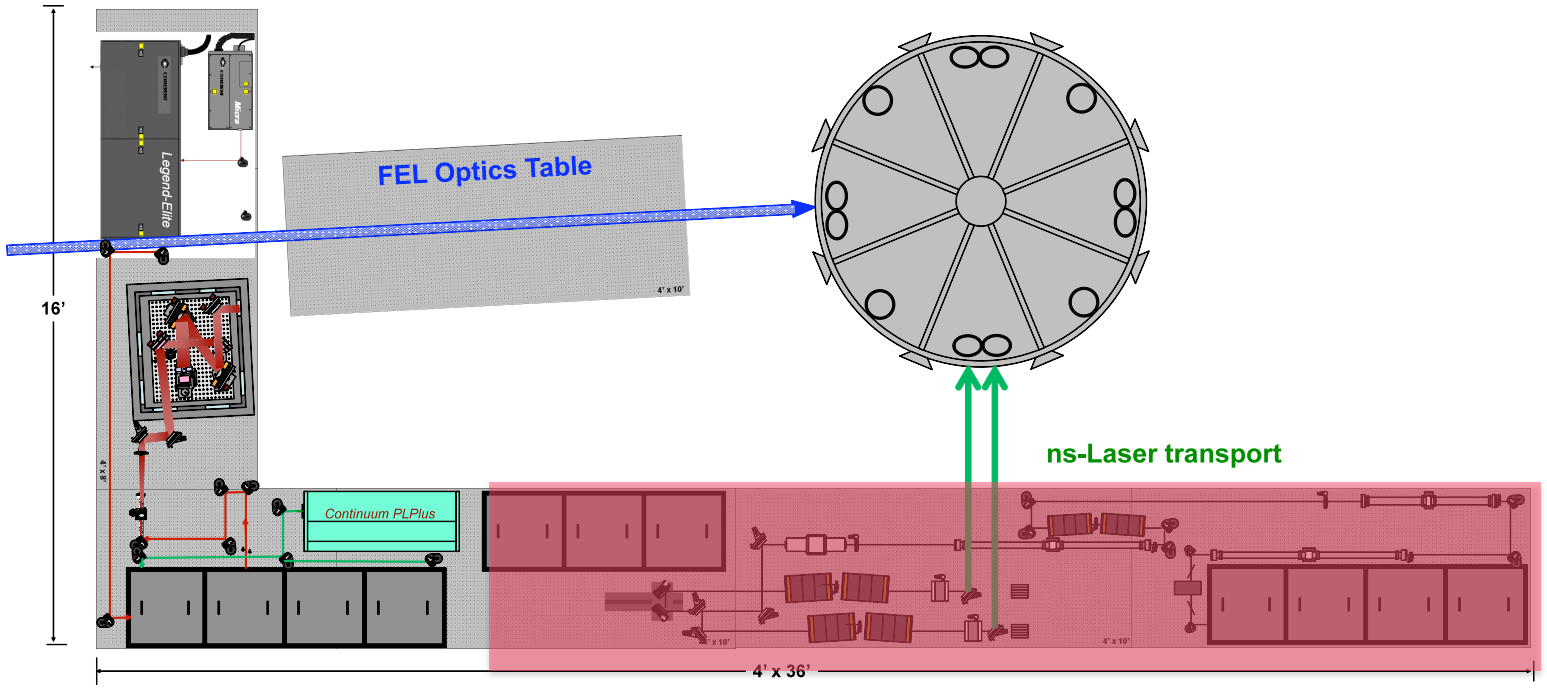




- MEC is a hard x-ray instrument: 2–10 keV photon energy.
- Soft x-ray HEDP experiments have be done at the AMO and SXR instruments.

Long pulse laser system

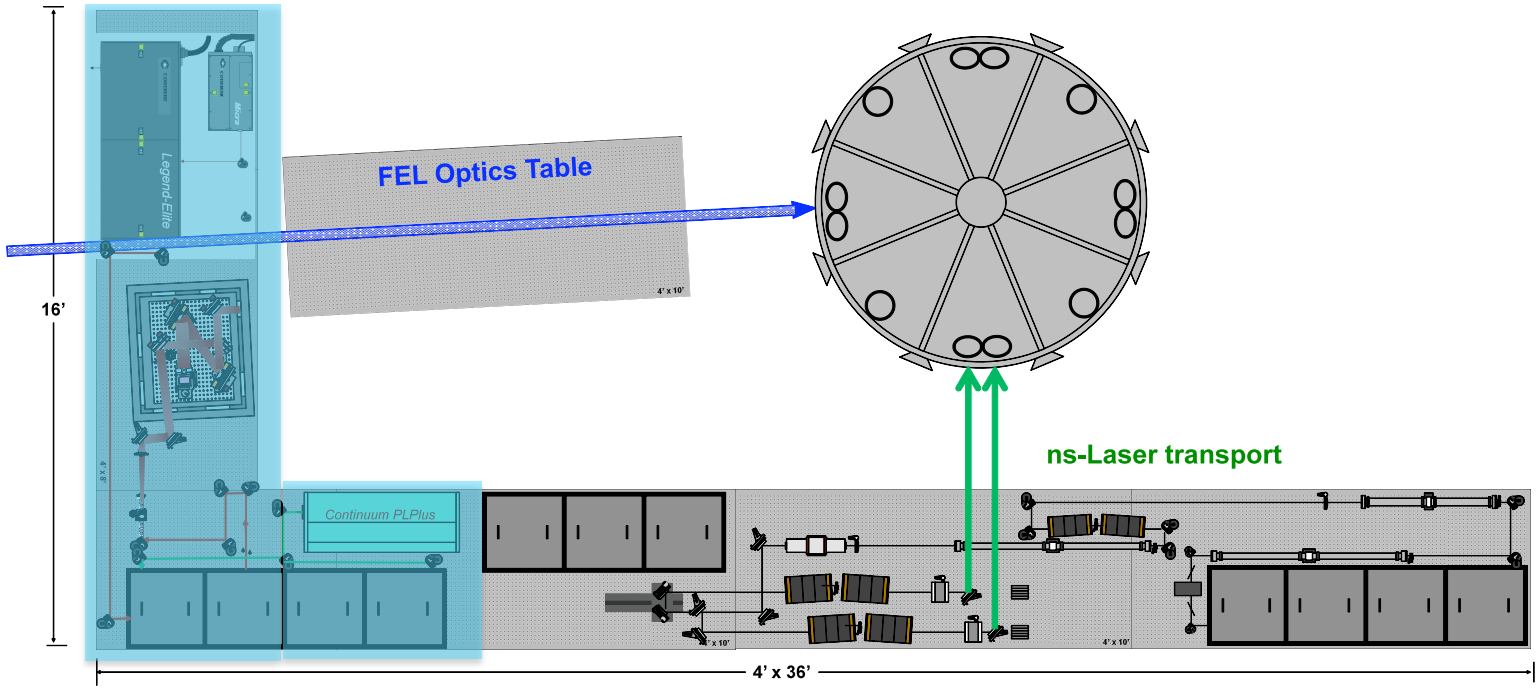
- Generates high pressure states



Long Pulse Laser	
Wavelength	527 nm
Pulse Width	2-200 ns
Repetition Rate	1 shot per 10 minutes
Pulse Energy	2 x 15 Joules

Short pulse laser system

- Heating at constant density



Short Pulse Laser	
Wavelength	800 nm
Pulse Width	35 fs
Repetition Rate	10 Hz
Pulse Energy	120 mJ

MEC Target Diagnostics: VISAR, FDI

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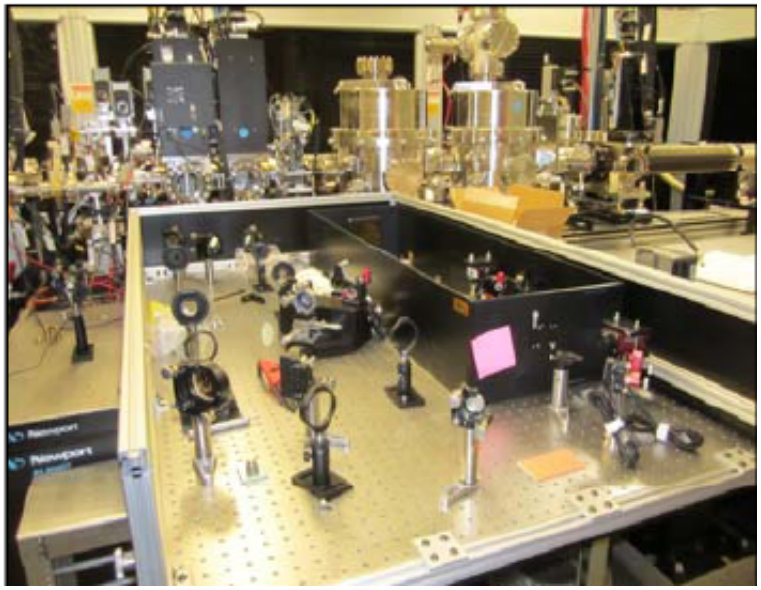
Velocity Interferometer System for Any Reflector (VISAR)

Fourier Domain Interferometer (FDI)



Item	*Purpose*	*Specification*
VISAR	*Measure shock velocity*	*Nanosecond time scale* $5x10^4 \sim 5x10^6$ *cm/s*
Fourier Domain Interferometer (FDI)	*Measure surface motion*	*Accurate to* $\lambda/100$ *for 800 nm probe*

MEC Target Diagnostics: XRTS, XUV

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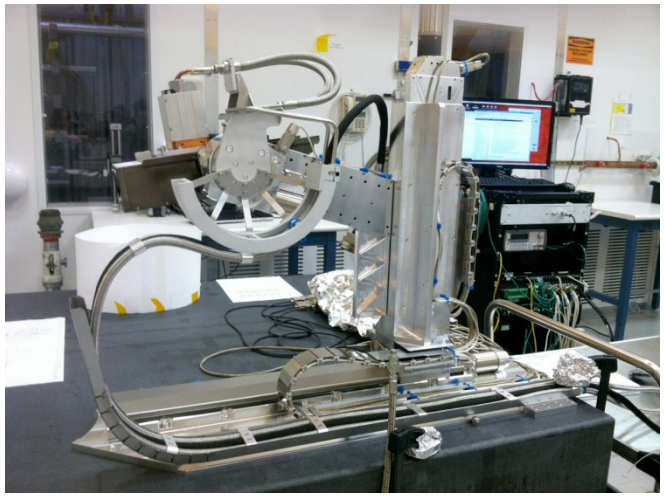
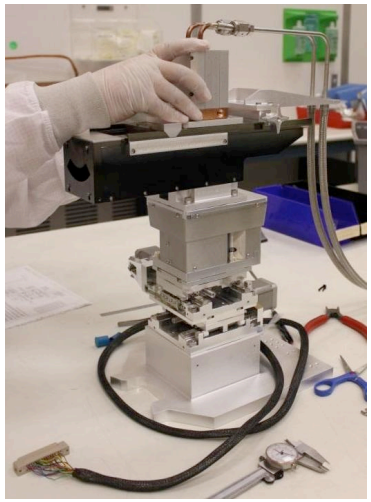
Forward Scattering X-ray spectrometer



Backward Scattering X-ray spectrometer



XUV spectrometer

Item	*Purpose*	*Specification*
X-ray Scattering Spectrometer (XRTS)	*Measure electron density and temperature* *Forward XRTS: automatic change of scattering angle, 0°< θs <90°*	*Spectral resolution of $\Delta E/E \sim 4\times10^{-3}$ at 8 keV* *temperature (1 ~ 100 eV)*
XUV spectroscopy	*Measure electron temperature and study electronic band structures*	*Spectral resolving power of $\lambda/\Delta\lambda \sim 300$ at 21 nm* *temperature (0.1 ~ 50 eV)*

Summary

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- The LCLS is the first hard x-ray FEL.
  - It began operations in 2009.
- LCLS MEC instrument has been in operation since April 2012.
  - X-ray optics and diagnostics
  - Long and short pulse laser systems
  - Target diagnostics
- HEDP experiments at LCLS (Bob Nagler tomorrow).

End of Presentation

LCLS Collaborations

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- Soft x-ray self-seeding
  - LBNL: Mechanical engineering
  - PSI: X-ray optics
- LCLS-II
  - LBNL: Undulators